



Horizontal Wells Boost CBM Recovery

By R.J. "Bob" Stayton

HOUSTON—Long considered uneconomic and hazardous, coalbed methane recovery has become increasingly popular for its economic benefits associated with the shallow depths typical of coalbed methane wells and the rich, long-lived volumes of methane stored within the coals.

Coalbed methane represents a significant energy resource, with 155 trillion cubic feet of methane contained within domestic coal basins, according to the Potential Gas Committee at the Colorado School of Mines. It is also a growing part of the nation's natural gas supply base, with lower-48 coalbed methane production rapidly approaching 1.5 Tcf, or almost 8 percent of annual U.S. gas production. A decade ago, significant commercial coalbed methane production was confined to the Black Warrior Basin in Alabama and the San Juan Basin in Colorado and New Mexico. Today, coalbed methane is being produced in the Appalachian, Cahaba, Piceance, Uinta, Powder River, Raton, Greater Green River, Arkoma, Cherokee, Forest City, and Illinois basins.

Advances in drilling technology have enabled producers to migrate into coalbed methane trends and transform "coal gas" into a profitable and environmentally friendly energy source. One of the most advantageous recovery methods to evolve through technological progress is the process of drilling coal seams horizontally. Horizontal drilling for coalbed methane accounted for nearly 10 percent of the total U.S. land wells drilled in 2000. Seventy-seven percent (8.1 Tcf) of proved coalbed methane reserves are located in the Rocky Mountain region, with the majority of production occurring in the Powder River Basin in Wyoming.

Benefits Of Horizontal Drilling

Coalbeds are characterized as aquifers in which gas has formed from chemical reactions during the coalification process. The gas absorbs into the micropores of the coal and is contained within the buried coal by water pressure. Methane is released when the water pressure is reduced by pumping from either vertical or inclined to horizontal surface holes. The gas then diffuses through cleats and nat-

ural fractures in the coalbed toward the well bore, where it is extracted.

While horizontal drilling is typically associated with higher costs, the benefits of its application to coalbed methane wells far outweigh the cost. By deviating from a vertical slope, horizontal drilling by its nature increases the drainage area for methane, which accelerates the dewatering of the coal seams, thereby increasing the rate of gas desorption. Depending on the length of horizontal section, one single lateral could drain seven times the area of a typical vertical well. Horizontal drilling also makes a more effective connection between the well bore and the natural fracture system of the coal reservoir, reducing the need for hydraulic fracture stimulation.

Advances in horizontal drilling also facilitate multilaterals from a single main well bore. By radiating in different directions, producers can contact more of the reservoir and recover more resources from one main well. With fewer facilities needed on the surface, horizontal drilling also reduces the environmental impact by reducing the well site footprint and enabling access to outlying reservoirs.

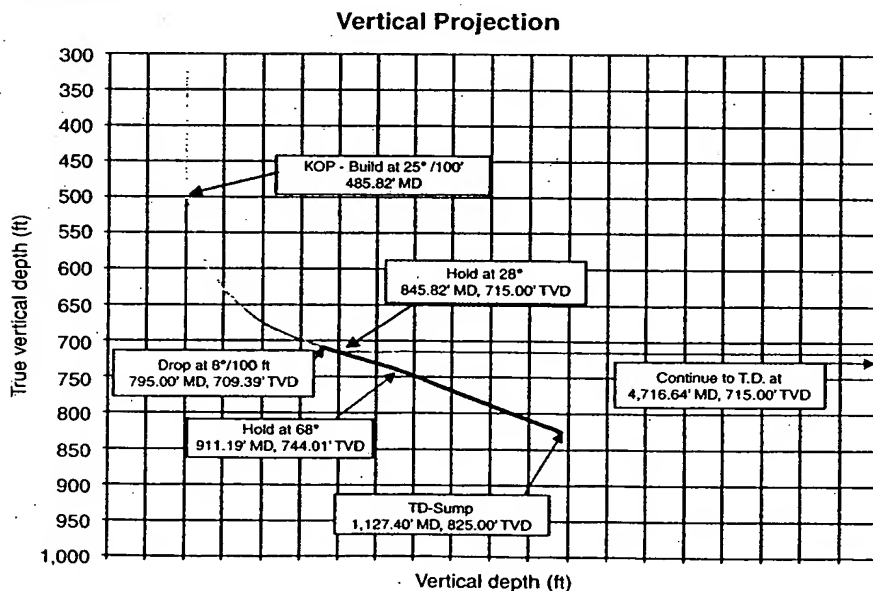
Improved safety is one of the most significant benefits to horizontal drilling in coalbed methane. The presence of gas within coal has been a major issue in underground coal mining since the coal industry's inception. The danger during mining lies in the explosive mixture of air and methane caused by gas leaking into the atmosphere from the pressure differential between the body of the coal seam and the coal's surface exposed in the mine. Horizontal drilling remains a much safer alternative because the coal is degassed from the surface. This process also enables deeper mining and faster mining rates, which lowers production costs and increases reserve size.

Planning The Project

Fundamental to the planning of a horizontal coalbed methane drilling project is a review of coal seam depth and the number of seams to be degasified or produced in a multiple seam scenario. These variables will determine the build rates required to intersect the seams. Some

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FIGURE 1



This figure shows the profile along the azimuth of a coalbed methane well. For the tie-on sump, the build rate was dropped to 8 degrees/100 feet, with a measured depth of 795 feet and true vertical depth of 709 feet.



coal seams are too deep to be profitably mined. Nevertheless, operators can drill into the coal seam, insert production piping and perforate opposite the target zone to produce methane.

Coal seam thickness is also important, since it determines the attainable horizontal displacement. Thicker beds are ideal targets for enhanced coalbed methane recovery, with thickness ranging from between 2.5 and 8 feet.

Planning reservoir drainage and mining is crucial in maximizing methane drainage benefits and production efficiencies. The objective is to dewater coal and adjacent strata to reduce formation pressure, and consequently, cause the gas to desorb. Knowledge of site geological and reservoir conditions such as in-situ gas contents and desorption characteristics, as well as mining logistics, will help engineers plan operations to maximize drainage benefits.

Another factor to consider is hole size and casing design. Hole size configurations generally are either 5 1/4-inch curve sections followed by 4 1/4-inch laterals, or 8 3/4-inch curve sections with 6 1/4-inch laterals. Hole size selection depends on upper hole stability and completion/production philosophies. To enable the higher build rates to be utilized, a smaller hole size is drilled first and then opened prior to drilling the laterals. The larger hole opening eases the running of casing through build sections.

Should casing be required through part of the coal, aluminum and or fiberglass casing may be a consideration if mining is to occur after coal degasification. An extended pilot hole below the coal can be utilized for a sump to allow the inflow of water, as well as for the base for the downhole pumps for water extraction.

The stability of the zones drilled prior to the target coal should also be considered to determine if casing is required to maintain well bore integrity throughout its production life. It can also be a determining factor in the probability of the drill string becoming stuck while drilling the lateral.

Coal type must be identified to determine gas content, reservoir pressure and the resulting drilling method (underbalanced or balanced). To some extent, most fluids damage coal. Therefore, an air/mist or foam drilling system (two-phase) should be considered when planning coalbed methane wells.

Rig selection should also be a primary consideration before undertaking a horizontal coalbed methane project. The shallow depths typical of coalbed methane wells may require a rig with pull-down capability. In multilateral profiles, weight is needed to sidetrack the main lateral well bore and to achieve 3,000- to 4,000-foot lateral displacement in the coal.

Top drive units offer additional weight for sliding and to start drilling when it is difficult to get weight to the bit. Top drive capability also affords the opportunity to backream and assist in mechanically agitating the hole to reduce cuttings bed buildup in the horizontal section of the well bore. The ability to drill entire stands reduces stationary time in the well bore and less opportunity to become differentially stuck.

A good hydraulics and/or air package assists in keeping the hole clean and ensures hole cleaning during drilling. The ability to track annular pressure in real time helps in monitoring hole cleaning. Modeling the required injection rates to achieve the required downhole pressure, annular velocity, surface pressure and total equivalent flow rate through the downhole motor is recommended to reduce the occurrence of unexpected events on location. The effect of different hole

and drill pipe sizes can be modeled, and the results can be compared to determine the best configuration.

Additional factors to consider in the planning process include planned horizontal distance and the fracture orientation of the cleats.

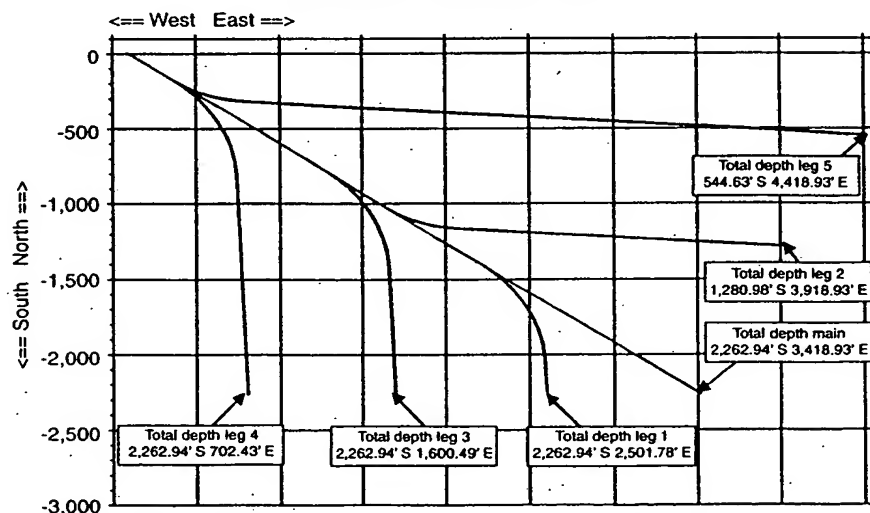
Drilling the Curve

The build sections of horizontal coalbed methane wells utilize typical build rates of 22-40 degrees per 100 feet based on coal seam quantity and depth, as well as other factors considered in the planning phase (Figures 1 and 2). Although higher build rates are achievable for certain hole sizes, it is not recommended if there is any geological uncertainty and higher-strength casing with special connections may be required. All drilling equipment has limitations with respect to dog-leg severity, or the change in inclination and azimuth per 100 feet, and is an important factor in selecting build rates and planning coalbed methane wells.

Build assemblies that incorporate a bit, downhole motor and a measurement-while-drilling (MWD) system are utilized to achieve the required build rates and are typically run in a slide-only scenario. In those cases where exact coal depths are unknown, the curve section is planned with a second lower build rate

FIGURE 2

Horizontal Projection Plan



Horizontal drilling facilitates the completion of multiple coal seams in a single well bore. This approach is less costly, has less impact on the environment, and enhances production of reserves. This figure shows a horizontal plan with five multilaterals drilled off the main well bore, with three reaching maximum depth of 2,263 feet.



to allow the well to be "soft landed" in the coal while drilling continues into the coal seam. This typically requires a trip to change the adjustable bend housing setting on the downhole motor.

Selecting an MWD system for geosteering is based on the fluid medium to be used in drilling the well. Mud-pulse systems can be employed in those cases where single-phase fluids are utilized. In cases where a two-phase drilling medium is used, an electromagnetic (EM) MWD system is typically applied. EM MWD has greatly reduced survey time and achieved substantial cost savings in coalbed methane projects.

Today's advanced horizontal systems enable horizontal drilling in coal seams as thin as 24 inches. Drilling within such thin seams can present a unique challenge. Porpoising in and out of the coal will minimize methane production and substantially increase the amount of torque and drag in the well bore, and reduce the horizontal distance that is capable of being drilled.

Staying in the Pay Zone

A key method to help stay in thin seams where there is enough difference to determine the top and bottom of the coal is real-time oriented gamma ray (OGR). The main lateral leg is drilled first and pulled back, and then lateral sidetracks are drilled off the main leg. As many as 12 branches have been drilled off one main leg, totaling 24,000 feet of lateral exposure in the coal using this technique.

As the lateral is drilled, several factors affect the ability to stay in the coal seam. As displacement increases, the coal dip may thin out or encounter geologic features such as anticlines and synclines that may make staying in the zone impossible. Attempting to follow these abrupt changes should be considered carefully, since it can significantly shorten attainable lateral lengths.

OGR indicates when the well bore exits the seam by transmitting gamma measurements of the top and bottom of the zone (Figure 3). The tool's depth of investigation is between six and 12 inches, depending on collar sizes.

The tool has an unshielded window that provides an azimuthal gamma ray measurement by utilizing an accelerometer to determine orientation and then translates the data into gamma ray up and down counts. These azimuthal measurements help determine if the well bore exited the top or bottom of coal, and makes it easier to determine how to steer back into the pay. A decelerating rate of penetration also indicates when the pipe enters harder formations.

Rotary gamma measurement saves time, allowing drilling to continue as the tool determines up and down gamma counts. Static checks can also be made when sliding. The OGR tool can reduce sidetracks, producing a better profile.

Prior to 1999, an operator was averaging one sidetrack for each branch drilled in order to stay in the pay. Today, the majority of a 10-leg well may have only one sidetrack per well using dynam-

ic OGR tools. Instantaneous rates of penetration have exceeded 200 feet an hour, and more than 3,000 feet of coal seam can be drilled in a single day, depending on coal quality and thickness.

Electromagnetic MWD technology is a key differentiator in horizontal drilling in coalbed methane wells. EM telemetry combined with the OGR provides accurate geosteering through the coalbed with reduced stationary time and maximized "in pay" footage.

With the EM tool, directional drillers can receive directional, pressure, gamma ray and 2-megaHertz resistivity measurements while drilling underbalanced or in two-phase flow conditions. Low-frequency electromagnetic waves transmit downhole measured data in real time to the surface during conventional and underbalanced horizontal and directional drilling operations. The information is transmitted in electromagnetic waves through the formation to a surface antenna, where it is received and sent to a surface transceiver to be decoded and processed.

Data are transmitted during connections when pumps are off, rather than requiring pump-up sequences like conventional mud-pulse telemetry. Once a connection is made, drilling can resume immediately, which ultimately saves on drilling time.

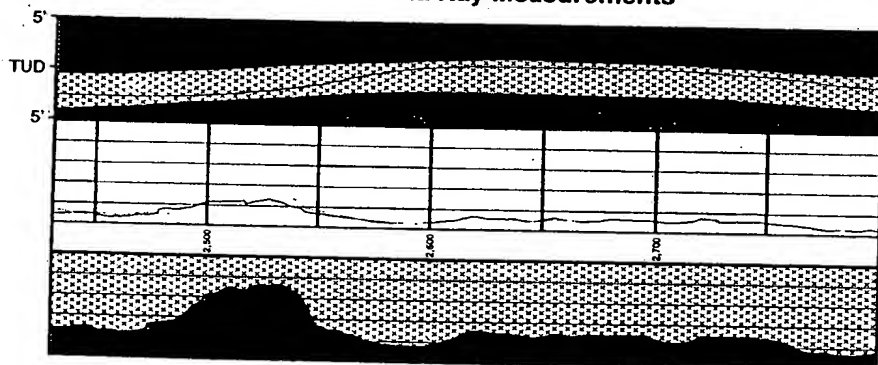
The EM tool also enables drilling and surveying of horizontal wells independent of rig hydraulics. Bit pressure drop, flow rate, and losses to the formation are transparent to EM technology. A minimum amount of pumped fluid is required to set up a conductive medium for signal transmission and dampening of internal components.

The cross-sectional flow area of the tool's nonmagnetic drill collar is equivalent to that of a standard drill collar. This design feature does not create any additional pressure losses and will not restrict the use of lost circulation material.

EM MWD technology can provide annular pressure, oriented gamma ray, resistivity, and standard gamma ray measurements. All survey data are stored in a database, including data transmitted in real time. The real-time data for gamma ray and annulus pressure are also stored in the downhole tool memory. The continuous annular pressure readout provides an indicator of drill cuttings buildup in the well bore and accurate reservoir pres-

FIGURE 3

Oriented Gamma Ray Measurements



An oriented gamma ray measures gamma counts and transmits the data to the surface to alert the directional driller when the well bore is leaving the coalbed. High gamma counts indicate shale, while low gamma counts indicate sand. OGR is key to maximizing footage while in the pay zone.



sure even when tripping. Short flow tests can also be conducted to verify production capability.

Data transmission can also be modified to optimize power consumption and maximize battery life by tailoring transmission requirements to particular drilling environments.

Unlocking The Potential

As demand for gas consumption overshadows the supply of conventional gas, greater emphasis is being placed on the production of unconventional reservoirs such as coalbed methane. Like other types of unconventional gas plays, coalbed methane represents a substantial energy resource with large potential reserves. Technology is the key to unlocking that potential and developing the reserves.

Although there has been coalbed methane exploration and production activity over the last 25 years, it has only been in the last five years that the E&P industry has begun to seriously target coalbed methane as a supply resource to

help meet the nation's growing demand for gas. As operators develop coalbed methane reservoirs, they are learning how to apply technology to improve well performance and recovery rates.

Implementing horizontal drilling in coalbed methane helps operators recover coalbed methane in the most economical and efficient means. The lessons learned to date in developing coalbed methane emphasize the importance of thorough up-front planning and applying advanced drilling technologies such as OGR and EM MWD as enabling technologies that enhance the drilling process in a reduced risk environment, and ultimately, improve well recoveries. OGR technology has quickly become a primary tool for maximizing "in pay" footage, and when combined with EM MWD, the steering devices maximize horizontal distance and gas production.

These results and others from coalbed methane projects have demonstrated that the ability to drill horizontally to produce coalbed methane reservoirs is economically efficient, profitable, safe and has

less impact on the environment than traditional drilling practices. Horizontal drilling represents an important and efficient method for future coalbed methane exploration and production. □

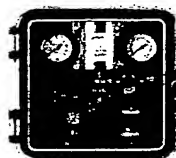
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